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ABSTRACT

THE EFFECTS OF MEDITATION TRAINING
ON VIGILANCE PERFORMANCE

By

Hal Maynard Clark

May 1988

This study investigated the relationships that exist between meditation training, vigilance performance, and thought intrusions. Twenty-four subjects performed a vigilance task in which hit rates, false alarm rates, and measures of SDT were recorded. Twelve of these subjects were then given four 30-minute meditation training sessions. Subjects were instructed to report thought intrusions during each training session. Following training, all 24 subjects performed the vigilance task again.

A vigilance decrement was found for hit rate and appears to have been caused by a sensitivity decrement. Meditation training did not significantly reduce the vigilance decrement or improve overall hit-rate performance. However, reported thought intrusions declined significantly over training sessions, and a significant

inverse relationship was found between thought intrusions and hit rate. The inverse relationship increased in strength with meditation training. These findings suggest that hit rate performance on a vigilance task may be improved with more extensive meditation training.

THE EFFECTS OF MEDITATION TRAINING
ON VIGILANCE PERFORMANCE

A THESIS

Presented to The Department of Psychology

California State University, Long Beach

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

By Hal Maynard Clark

B.A., 1981, California State University, Sacramento

May 1988

WE, THE UNDERSIGNED MEMBERS OF THE COMMITTEE,

HAVE APPROVED THIS THESIS

THE EFFECTS OF MEDITATION TRAINING

ON VIGILANCE PERFORMANCE

By

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CHAPTER 1

Introduction

The human ability to sustain directed attention is utilized constantly in daily living and is often essential to physical survival itself. Tasks such as reading a book, or driving a car would be impossible if it were not for the ability to maintain focused attention. The study of vigilance or monitoring behavior is pursued out of a desire to understand and control sustained attention so that its utilization in applied settings can be optimized.

Of primary concern to researchers are the unstable characteristics of attention when required for extended periods of time. Vigilance tasks that are long and monotonous are often accompanied by a progressive decline in detection rate or response latency performance. This decline in performance is called the vigilance decrement. While many of the task variables that contribute to the vigilance decrement have been identified, little has been done in the area of training methods that would improve an individual's level of vigilance performance. The purpose of this study is to demonstrate the effect of a training intervention aimed at improving the ability to sustain attention.

Human-factors specialists need to know if sustained attention can be improved with training or whether solutions to the vigilance decrement must come from hardware design. The introduction of new technologies into the work place has aggravated the problem by creating new jobs that require operators to monitor equipment and displays for long periods of time. Many of these jobs are inherently dangerous to the worker and/or machine because they do not take into consideration the instability of sustained attention over time.

A massive body of research on vigilance has accumulated over the past 40 years. Various theories have been put forth in an attempt to explain vigilance decrement but none have gone uncontested. Most of the research has focused on identifying elements within the vigilance task that affect vigilance performance. While some of the variables have met with general acceptance, others are not so clear, due to contradictory findings.

Vigilance Decrement

N. H. Mackworth (1948) is credited with carrying out the first controlled laboratory experiments in vigilance. During World War II he was called upon by the British Royal Air Force to examine the problem of vigilance decrement during radar monitoring. Military radar operators, searching for submarines off the British coast, were

routinely missing critical target signals during extended periods of radar monitoring.

In order to study vigilance decrement, N. H. Mackworth (1948) created the Clock Test, a laboratory task that simulated characteristics found in radar monitoring. It consisted of a clock-like device in which a black pointer rotated over a white background. The pointer moved in small equal increments around the face, and at infrequent intervals the pointer would make a double jump. A double jump represented the critical signal to be detected. In this experiment the event rate was 60 per minute, which represented the sum total of signal and nonsignal movements of the pointer in one minute. The signal rate was 24 double jumps per hour, with each signal taking the place of a nonsignal event. Intersignal intervals were predetermined and varied from 1 to 10 minutes. Performance on the Clock Test was measured in percentage of signals missed per half hour. In the two groups which performed the task for one hour, an average of 14.15% of the signals were missed in the first half hour and an average of 27.3% in the second half hour. This progressive decline in performance was demonstrated across several independent groups which received one- or two-hour sessions.

Once it became known in the research community that a vigilance decrement could be produced in a laboratory setting, many studies were conducted to determine what

effect different task parameters had on vigilance performance.

Task Parameters that Affect Vigilance Performance

Vigilance decrement and overall performance have been shown to be sensitive to a variety of task variables. Variables such as event rate, signal probability, signal rate, intersignal interval, signal conspicuity, and sensory modality need to be considered when different studies are compared. The effects each of these variables have on vigilance performance are briefly discussed next.

Event Rate

Jerison and Pickett (1964) found that a high event rate was more likely to produce a vigilance decrement than a low event rate. In their experiment they looked specifically at event rates of 5 and 30 per minute while holding the signal rate constant at 15 per hour. Signal detection with the high event rate dropped from 60% during the first 20 minutes to 30% towards the end of the session. In contrast, a low event rate produced consistently high signal detection rates above 80% with no decrement over time. Others have since confirmed the finding that vigilance performance is inversely related to task event rate (Jerison, Pickett, & Stenson, 1965; Johnston, Howell, & Goldstein, 1966; J. F. Mackworth, 1965).

Signal Probability

Jerison (1967a) also studied the effect of signal probability on vigilance performance, as it relates to event rate. Six levels of signal probability were studied, ranging between .0083 and .05. Signal probabilities were established by holding the number of critical signals constant at 15 per hour, while event rate was increased in increments for the different conditions to produce lower signal probabilities. Event rates ranged from 5 to 30 events per minute. Results showed that percent signal detections increased as a direct linear function of signal probability up to a probability of about .02 at which point it appears to reach an asymptote. This finding was consistent with the previous study by Jerison and Picket (1964) which found that a low event rate with a signal probability of .05 produced higher signal detection performance than a high event rate with a signal probability of .0083.

Signal Rate

Signal rate has been found to have an even greater impact on signal detection than event rate. Using a version of Mackworth's Clock Test, Jenkins (1958) tested the effects of four different signal rates (7.5, 30, 60, 480 per hour) on vigilance performance. He found that signal detection rate varied directly as a function of signal rate, with the effect becoming more pronounced as

the vigilance task progressed in time. A vigilance decrement still occurred across all signal rates but was almost completely attenuated at the 480-per-hour rate. Of course, holding the event rate constant at 60 per minute, signal probability would increase as signal rate increased, a fact which may partially account for the higher signal detection rates found by Jenkins (1958). However, the effect of signal probability on detection rate is negligible above a probability of .02 (Jerison, 1967a), and any additional increase in detection rate at higher signal probabilities would most likely be due entirely to signal rate. Other studies have also found signal rate to be directly related to detection rate (Niceley & Miller, 1957; Wiener, 1963).

Intersignal Interval

Both the duration and variability of intersignal time intervals have an impact on signal detection performance. Variability of the intersignal interval has been found to be directly related to signal detection performance, but there exists an inverse relationship between duration and performance (Dardano, 1962; McCormack & Prysiazniuk, 1961; Warm, Epps, & Ferguson, 1974). Temporal uncertainty increases with intersignal interval duration and variability, making it more difficult to establish accurate expectations about future signals.

Signal Conspicuity

Studies on signal conspicuity tend to confirm common-sense expectations. If you make a critical signal louder, brighter, or present it longer, its detectability will be enhanced. This can either increase signal detection rates or decrease response latencies (Adams, 1956; Lisper, Kjellberg, & Melin, 1972; Metzger, Warm, & Senter, 1974). The Loeb and Binford (1968) study that investigated the effects of different sound levels on signal detection in an auditory vigilance task, is typical of the research in this area. Subjects were required to detect small occasional increases in sound pulses that were 2.1, 3.6, or 5.1 dB above the neutral sound pulses that were set at 60 dB above the subject's absolute threshold. As expected, detectability of critical signals was enhanced as sound level increased.

Sensory Modality

The common practice of generalizing findings across visual, tactile and auditory sensory modalities is based on the notion of a unitary "factor" of sustained attention. However, the vigilance decrement, which occurs in all three modalities, has been reported to be less pronounced in auditory vigilance tasks than in tactile or visual tasks (Hawkes & Loeb, 1961; Ware, 1961). Hatfield and Loeb (1968) have suggested that differences in findings between modalities can be attributed to the way in which the

stimulus is presented to the subjects. For a visual stimulus to be perceived, the eyes must be open and oriented in the proper direction, unlike auditory and tactile stimuli which can be perceived at all times regardless of body orientation. In Hatfield and Loeb (1968), subjects had their eyes taped shut and light pulses were presented that could be detected through the eyelids. Subjects were required to monitor for small changes in the intensity of the pulses. By coupling the visual stimulus in this manner, head movement and eye blinks were no longer a factor. Speed and accuracy of signal detection exceeded that obtained under free observing conditions, reaching a level of performance similar to auditory vigilance tasks.

It is clear, from the above discussion, that task parameters are an important consideration when using a vigilance task to study sustained attention. The ability to generalize findings is dependent upon the use of similar task parameters. Understanding the effects of task parameters on vigilance performance is important, but it does not explain the psychological or physiological causes that lie behind the vigilance decrement. Vigilance researchers have increasingly turned to Signal Detection Theory (SDT) to provide the answers in this area.

Signal Detection Theory as Model of Vigilance Performance

Many theories have been put forth in an attempt to explain why vigilance performance, as measured by detection rate or reaction time, tends to deteriorate as a function of time on task. The various theories are generally based upon either learning, neurological, information processing, or psychophysical models. Signal detection theory (SDT), which is normally used in the analysis of detection performance in psychophysical experiments, has become the most commonly accepted model for explaining human vigilance. The main advantage of SDT is that it provides separate measures for signal detectability and decision criterion by incorporating both detection rate and false-alarm data into the model. The term "false alarm" refers to decision errors made by subjects in which neutral events are identified as critical signals.

Past studies that have used SDT to explain vigilance decrement are divided on the issue of whether the decrement is caused by a criterion increment or a perceptual sensitivity decrement. The more widely held view is that vigilance decrement is caused by a shift to a more conservative criterion over the watch (Broadbent & Gregory, 1963). Studies that support this view have found that both detection rates and false-alarm rates decline over time within the watch. However, J. F. Mackworth and Taylor (1963), as

well as others, have found just the opposite to be true. Both signal detections and perceptual sensitivity declined together as a function of time on watch with no significant changes in criterion. Studies which found sensitivity decrements were slow to be accepted in the research community since it was believed that sensitivity remained constant in a vigilance task.

To determine if task characteristics were responsible for the contradictory findings pertaining to SDT measures of criterion and sensitivity, Parasuraman (1979) conducted a comprehensive survey of vigilance studies that used SDT measures in their analyses. They classified the various studies along four dimensions: event rate, sense modality, task complexity, and whether the task required a simultaneous or successive discrimination. In a simultaneous-discrimination task, target signals are presented simultaneously with a reference standard for comparison. This is in contrast to a successive-discrimination task in which no reference is provided during target signal events. Subjects must hold the standard in memory in order to discriminate between neutral and target signals. Parasuraman showed that studies using successive-discrimination tasks and high event rates (greater than 24 per minute) were the only ones that found a sensitivity decrement to account for their results. Studies that used a simultaneous-discrimination task, regardless of any other factors,

attributed their results to a criterion shift. It was concluded that a sensitivity decrement would only occur in studies that used a successive-discrimination task with a high event rate.

The application of SDT methodology to the vigilance situation has not gone uncontested, but is strongly criticized by some (Craig, 1979; Jerison et al., 1965; Jerison, 1967b). Jerison (1967b) pointed out several problems associated with SDT as it relates to vigilance. SDT was originally intended as a model to explain findings in psychophysical experiments in which weak signals had to be detected amid a background of noise. This is in contrast to vigilance tasks in which the signal is usually designed to be highly detectable. As a result, false alarms are often nonexistent, a fact which distorts the sensitivity and criterion values, making them uninterpretable in conventional terms. Another problem is that SDT indices of sensitivity and response criterion are based on the assumptions of normal distributions and equal variances. Since these assumptions are rarely met in most vigilance experiments, nonparametric indices of perceptual sensitivity and response criterion have been recommended as a solution (Craig, 1979). One approach has been to derive sensitivity and bias measures from the geometry of the unit square (Hodos, 1970; Pollack & Norman, 1964), as discussed in Appendix A.

A more serious problem with SDT, as seen by Jerison (1967b), is that SDT fails to address the attention variables that are critical to a vigilance task. SDT assumes that observers maintain a constant attentiveness to the task, such that all signal and nonsignal events are observed and that the only decisions being made have to do with deciding whether a stimulus was a signal or nonsignal. It is highly likely that observers also make decisions on how to observe, which may result in less efficient observing behavior such as daydreaming or even sleeping. Any activity that degrades the observing behavior will cause a simultaneous drop in hit rate and false-alarm rate which in turn will distort any SDT measures that are based on those two parameters.

Davies and Parasuraman (1982) qualify their acceptance of SDT by stating that "the marriage of SDT and vigilance is not a perfect one, and that in certain situations some assumptions will not be met" (p. 59). However, they believe that if it is applied with caution it can provide a more complete understanding of the processes underlying vigilance behavior. Their view is that SDT is not perfect but that it can be modified in various ways to make its use in the vigilance paradigm acceptable.

Knowing whether a vigilance decrement is caused by a sensitivity decrement or by a criterion shift may have important implications when designing a training program to

improve vigilance performance. There is a shortage of research in the area of training as it relates to vigilance. The areas that have been studied are discussed below.

Effects of Vigilance Training

Given the large number of jobs that require monitoring duties in the workplace, it is essential that training methods be developed that allow operators to improve their vigilance performance. An area that has received relatively little attention is that of vigilance training. Of the research that has been done to date, the application of performance feedback has received most of the attention, followed by research into practice effects.

Knowledge of Results

Feedback in the form of knowledge of results (KR) has been shown to reduce the vigilance decrement while improving overall detection rate and reaction time. Types of information provided to subjects include, correct hits, false alarms, missed signals, and in some cases false feedback. J. F. Mackworth (1964) tested three forms of feedback, accurate KR, false KR and no KR in conjunction with the Clock Test. The false and accurate KR conditions produced higher overall signal detection rates than the no KR condition. Prior exposure to accurate KR enabled subjects to perform more efficiently on subsequent tasks with no KR. Adams and Humes (1963) have suggested that

observers are able to learn task-relevant information from accurate KR that enable them to establish more accurate expectations of signal probability and to become more familiar with the distinguishing characteristics of the critical signals. Others (e.g., McCormack, 1967) have maintained that the facilitative effects of KR are primarily motivational rather than instructive in character. The fact that false feedback tends to improve performance about as well as accurate feedback would support the contention that something other than the learning of task-relevant information is taking place. It may be that observers who think they are receiving accurate feedback are stimulated by the additional social interaction that feedback provides, whether or not the feedback is accurate.

Practice Effects

Researchers are divided as to the effects of practice on performance in a vigilance task. Webb and Wherry (1960) had subjects perform a nine-hour auditory vigilance task on five consecutive days, and found that signal detection rates did not improve. Their study was followed up by Ware, Sipowicz, and Baker (1961) using a similar auditory task in ten 90-minute sessions with the same results. Baker, Sipowicz, and Ware (1961) investigated the effects of practice in a visual monitoring task that required subjects to detect brief interruptions of a continuous

light source. No effect due to practice was found even though subjects received 15 sessions of 90 minutes each.

In contrast to the above studies, Colquhoun and Edwards (1970) found that detection rate improved substantially with practice in a visual task. The effects of three different vigilance tasks were studied: one required a visual search of six objects; one a discriminative judgment between two objects; and the third involved an absolute judgment of one object. While each group showed improvement over the eight 40-minute sessions, the amount of improvement was largely dependent upon the type of judgment required in the task. The group that had the visual search task showed the most improvement between sessions, followed by a modest improvement for those in the discriminative-judgment task, and only a small improvement for those in the absolute-judgment task. Other researchers have confirmed Colquhoun's findings that tasks requiring discriminative judgments or visual search are susceptible to practice effects (Gibson, 1953), but generally no practice effects have been found in other studies in which an absolute judgment task was used.

The use of KR to improve vigilance performance may have some potential in applied applications. However, the use of practice shows little promise as a training technique. A different approach would be to train people to have better control over their thought processes in a way

that improves their ability to maintain sustained attention. Understanding the effects that thought intrusions have on sustained attention may provide the key to this approach.

Effects of Thought Intrusions

In monitoring tasks that are long and monotonous, the occurrence of thought intrusions may represent a major obstacle to the maintenance of sustained attention. The term "thought intrusion," as used in this study, refers to any spontaneously generated thoughts that are unrelated to the object of attention. Thought intrusions are insidious in that their onset is instantaneous and without warning. Once they occur, they are capable of capturing and redirecting attention, which could degrade performance on a monitoring task.

The effects of thought intrusions on signal detection performance was studied by Antrobus, Coleman, and Singer (1967). They had 157 college students take the General Daydreaming Questionnaire (Singer & Antrobus, 1963) and the Thoughtfulness subscale of the Guilford-Zimmerman Temperament Survey, to provide a measure of daydreaming frequency and introversion of thought processes. The 10 highest and 10 lowest scorers were then selected as subjects for the signal detection task. An auditory detection task was used in which subjects had to discriminate between two highly discriminable tone pulses that

were presented at the rate of one per second. A rapid signal rate was used to provide sufficient external stimulation to maintain subjects at a normal waking level of arousal. Sessions were divided into 15-second trials (N = 100) for a total of 25 minutes. Subjects were provided with two response keys, one for responding to critical signals and the other for reporting the presence of thought intrusions at the end of each 15-second trial period. Results showed that "high daydreamers" reported a significantly higher number of thought intrusions than "low daydreamers." However, frequency of reported thought intrusions rose significantly between the first and last 25 trials in both groups. Overall detection accuracy was better for the low daydreamers, who had an error rate of 2.69% as compared to 5.55% for high daydreamers. Furthermore, the high daydreamers showed a significant performance decrement over time that was not observed in the low daydreamers. These results indicate that thought intrusions can adversely affect performance on a signal detection task, and point to the existence of a connection between thought intrusions and a daydreaming tendency.

Van Nuys (1971) demonstrated that thought intrusions could be used to study attention during meditation. Two meditation techniques were used, one involved an internal focus of attention on breathing rhythm and the other required an external focus on a candle flame. Subjects

first performed the candle meditation for 15 minutes followed by a short break, and then continued for another 15 minutes using the breathing awareness technique. During both sessions, subjects were instructed to press a handheld button in response to any thought intrusions that caused their attention to shift. Thought intrusions were found to be negatively correlated (r = -.42) with measures of hypnotic susceptibility, indicating that persons capable of high attentional absorption are able to maintain attention with fewer thought intrusions.

Craver (1984) replicated the Van Nuys (1971) self-report technique in a study designed to assess its reliability. Twelve subjects, with no prior meditation training, participated in four sessions. Each session consisted of a 10-minute meditation using a visual stimulus and a 10-minute meditation using an auditory stimulus. The visual stimulus was a white translucent panel (2 3/4 in. X 1 1/2 in.) placed five feet in front of the subject. The auditory stimulus consisted of white noise produced by a speaker, also five feet in front of the subject. Subjects were instructed to record thought intrusions during the visual and auditory meditation trials by using a hand counter. Based on total thought intrusion-scores, correlations between sessions were found to be moderate to high (r = .70 to .95). This was interpreted to mean that the

Van Nuys attention-assessing technique was a reliable method of collecting data on thought intrusions.

In summary, the research relating to thought intrusions has shown that thought intrusions can be measured by a self-report method, and that there may be a relationship between thought intrusions and vigilance performance. The effects of meditation training on human performance and attention will be discussed next.

Effects of Meditation

The practice of meditation, which is an integral part of several Eastern religions, was introduced into the United States during the 1970's, mostly due to the well-promoted training programs of the Transcendental Meditation (TM) organization. The word "meditation" is a generic term that stands for a variety of techniques that have certain characteristics in common. Central to most forms of meditation is a mental exercise in which a person consciously directs and maintains complete attention upon a predetermined point. Meditators claim that with practice they are able to eliminate thought intrusions so that their attention upon the point of focus is without interruption. The point of focus varies among techniques, but can include: breathing rhythm; external physical objects; repeated chant or mantra; ideas (abstract concepts); or imaginary points in space.

Several studies have established that meditation produces both short- and long-term effects. Short-term effects occur during or shortly after a meditation session. These include indications of lowered autonomic and cortical arousal such as: decreased oxygen consumption, increased skin resistance, decreased heart rate, decreased muscle tension, decreased systolic and diastolic blood pressure, and increased alpha and theta brain-wave activity (Banquet, 1973; Hafner, 1982; Wallace, 1970; Zaichkowsky & Kamen, 1978). Long-term effects that accrue from the regular practice of meditation include: enhanced attentive ability, improved physical performance, changes in perceptual style, and improved mental health (Appelle & Oswald, 1974; Davidson, Goleman, & Schwartz, 1976; Ferguson & Gowan, 1976; Hjelle, 1974; Warm, Seeman, Bean, Chin, & Wessling, 1977). Of particular interest to the present study are the long-term effects relating to attentional ability and human performance.

In a study by Appelle and Oswald (1974) the effects of prior mental activity on simple reaction time were investigated. Three different mental activities (meditation, rest, and number sorting) were performed by separate groups for 20 minutes. Before and after each activity, subjects were tested for simple reaction time (RT). To measure RT, subjects were instructed to press a pushbutton whenever a stimulus lamp illuminated, thereby terminating the light.

A tone was used to warn subjects a few seconds before light onset. Mean reaction times following the rest and meditation conditions remained unchanged from pretest, while the subjects assigned to the number-sorting condition were able to reduce their mean reaction time. However, only the meditation group showed a significant reduction in reaction-time variance, a finding which suggest the possibility that meditation produces a more constant state of alertness. While the study was mainly concerned with the short-term effects of prior mental activity on reaction time, long-term effects having to do with group membership were also found. The meditation group, made up of experienced TM meditators, were found to have mean reaction times ten percent faster on both the pretest and posttest as compared to the two groups formed by random selection. The results suggest that the superior RT performance of the meditators was due to a heightened level of alertness made possible by previous meditation training. If this is true then prior meditation training produced a confounding effect on RT that makes comparisons between groups difficult to interpret. Self-selection in the meditation group may also have been a factor in their higher overall RT performance.

Pelletier (1974) noted that one of the goals of meditation training was to gain greater awareness of internal stimuli and to increase the ability to focus attention. He predicted that meditation training would redirect the

deployment of attention from external toward internal stimuli, resulting in a corresponding shift in manifest perceptual style, which would be interpreted as reflecting greater ego distance and field independence. Forty volunteers were recruited as subjects from an introductory lecture for Transcendental Meditation (TM). Subjects were randomly assigned to the meditation group or the control group. The meditation group received instruction in TM and practiced meditation for three months, 20 minutes each morning; the control group was instructed to sit quietly for 20 minutes each morning. Three measures of perceptual style were administered (autokinetic effect, embedded-figures test, and rod-and-frame test) at the beginning and end of the three-month period. On the posttests, the meditation group demonstrated increased accuracy on the rod-and-frame test, shorter latency times on the embedded-figures test, and significant changes in three autokinetic measures. Autokinetic latency time decreased, while autokinetic length of line, and distance from center increased as determined by pencil tracings made by subjects in response to perceived movements of the light. These findings were taken to support the prediction that meditation training produces a shift in perceptual style towards greater ego distance and field independence. Pelletier (1974) concluded that "these observed differences can be

attributed to an alteration in the individual's deployment of attention due to meditative practice" (p. 1033).

The effects of meditation experience on vigilance performance was specifically addressed by Warm, Seeman, Bean, Chin, and Wessling (1977). They compared the performance of experienced meditators with candidates for meditation training and nonmeditators on a one-hour visual vigilance task that used a modified form of the Jerison and Pickett (1964) light bar presentation. An event consisted of the apparent movement of a light bar 2 mm wide and 18 mm high. The light would move 24 mm from left to right two times in quick succession to produce an event. Because the double deflection was rapid, the task was considered to be a simultaneous-discrimination task. A signal was produced by extending the distance between the light bars 4 mm on the second deflection of an event. The groups were split with half receiving a fast event rate and the other half a slow event rate of 21 and 6 events per minute respectively. Signal rate was held constant at 20 per hour. Experienced meditators demonstrated a higher overall detection rate than the candidate and nonmeditation groups across both event-rate conditions. Under the slow event-rate condition, a higher percentage of signals was detected by all three groups as a whole when compared against the fast event rate condition. In a plot of signal detection rates across time, the experienced meditators showed no vigilance

decrement within the fast event rate condition, as compared to decrements of over 20% for the other groups. Since the candidates for meditation training did no better on the vigilance task than the nonmeditators, self-selection in the meditation group was not a contributing factor to their superior performance. While the findings in this study suggest that meditation training enhances attentiveness, the study does not identify the factors within meditation that cause the effect. If meditators are in fact able to reduce their number of thought intrusions during meditation, then that ability may be the underlying factor that enables meditators to outperform nonmeditators on a vigilance task. The ability may transfer to the vigilance task in such a way that sustained attention is improved.

The Present Study

The objective of this study was to test further the implications of the Warm et al. (1977) study, in which experienced TM meditators were found to outperform nonmeditators in a vigilance task, and to explore the relationships between meditation training, thought intrusions and vigilance performance. Instead of using experienced TM meditators, subjects with no prior meditation experience were randomly assigned to treatment and control groups, to control against self-selection. The treatment group received two hours of noncultic meditation training under controlled conditions. By controlling the type and amount

of meditation training, effects produced by the training could be more accurately isolated and assessed. One objective of this study was to determine if short-term meditation training could improve vigilance performance to the same degree as experienced meditators in the Warm et al. (1977) study. Improved performance would indicate that the effects of meditation training are transferable to the vigilance task.

Subjects were required to report the occurrence of all thought intrusions during the four 30-minute meditation training sessions. Thought intrusions were tracked to determine if they were related to meditation progress and vigilance performance. The use of a noncultic meditation technique was used to control for any effects that might be related to religious teachings.

A visual vigilance task, known to produce a vigilance decrement, was used to measure vigilance performance before and after the training intervention. The vigilance task used a high event rate and required a simultaneous discrimination between two vertical lines. Difficulty level of the task was considered to be moderate to high.

In the analysis of the effects of meditation training on vigilance performance, the independent variables were meditation training (with and without), and time periods within the vigilance task (four 10-minute periods). The dependent variables included: signal detection rate,

false-alarm rate, and the nonparametric SDT measures of sensitivity (A') and criterion (B").

In a separate analysis that looked at the effects of meditation training on thought intrusions, meditation training sessions were treated as an independent variable (four 30-minute sessions), and thought intrusions served as the dependent variable. The appropriate dependent measures were used to test the following hypotheses.

Hypotheses

1. Short-term meditation training will reduce the degree of vigilance decrement that occurs over time within a vigilance task. In Warm et al. (1977), experienced meditators did not show as large a vigilance decrement as nonmeditators, so it follows that short-term meditation training may have the same effect.

2. Short-term meditation training will improve overall signal detection performance on a vigilance task. The study by Warm et al. (1977), in which meditation experience was shown to have an effect on overall vigilance performance, leads to this hypothesis, that short-term training would also have an effect.

3. Thought intrusions recorded during meditation training will be inversely related to overall performance on the vigilance task. Rationale for this hypothesis is provided by the Antrobus et al. (1967) study which found that the number of spontaneous thought intrusions reported

during a signal detection task was inversely related to signal detection rate.

4. Thought intrusions will decline as a function of time spent in meditation training. This follows from a review of the meditation literature by Van Nuys (1971) in which meditation training is claimed to facilitate the acquisition of skills needed to gain control over attentional processes.

CHAPTER 2

Method

Subjects

A total of 24 subjects participated, 12 of each gender. Six males and six females were randomly assigned to the treatment group. The other six of each gender served as the control group. All were students at California State University, Long Beach, with class levels ranging from sophomore to graduate. Their ages ranged from 20 to 42 with a mean of 26. All subjects had normal or corrected-to-normal vision, and reported no prior experience in meditation. Twenty of the subjects received class credit for their participation; the other four received $5.00 per hour. To equalize any effects caused by differences in compensation, the 20 subjects that received class credit were divided equally on a random basis between the treatment and control groups as were the four that received monetary compensation. Treatment group subjects were needed for four hours and control group subjects for two hours.

Apparatus

All training and testing was conducted in an audiometric chamber to eliminate distractions caused by

uncontrolled environmental noise. A comfortable arm chair was used to seat subjects during meditation training and vigilance testing. An Apple IIe computer and monitor were used to present the visual elements of the vigilance task and to record responses. The monitor was positioned on a table so that the face of the monitor was at eye level 30 inches forward from the surface of the chair's headrest. Thus the distance between the subject's eyes and the face of the monitor was fixed at approximately 24 inches. A glare control filter (Glare Trap by Inmac) was fitted to the face of the monitor to reduce afterimage, improve contrast, and eliminate reflections. During the vigilance task, the Apple IIe keyboard and diskdrives were mounted on a stand to the right of the chair at a height that enabled subjects to rest their fingers on the space bar without moving their arm from the armrest. A standard Apple computer hand controller was used to record responses during the meditation training. During meditation training the computer keyboard was moved about one foot to the side of the subject's chair and the hand controller was connected to it via a three-foot cord. A two-way intercommunications system was used to communicate with subjects while they were inside the chamber. Illumination was provided by a 25-watt incandescent lamp located behind the monitor, and directed towards the forward wall three feet away.

Stimuli

The vigilance task was 40 minutes in duration, during which time subjects visually monitored a CRT presentation. The presentation consisted of a pair of 20 mm by 1 mm vertical lines (visual angle = 1 degree 53 seconds) separated laterally by a distance of 15 mm, flashed at the center of the screen for 250 msec every two seconds. This equates to an event rate of 30 per minute, which is the total number of signal and nonsignal events presented. Critical signals for detection were similar to nonsignal events except that one of the two vertical lines (determined randomly) appeared longer at the top by 1 mm (visual angle = 5 minutes 24 seconds). The 40-minute vigil was divided into four consecutive 10-minute periods for scoring. The 10-minute periods were similar in terms of signal rate and intersignal intervals (ISI). Critical signals were presented on the average of one per minute, with ISIs ranging from 20 to 200 seconds. Thus signal probability was .03.

Research Design

A three-factor mixed-design was used in this experiment to determine the effects of meditation training on vigilance performance. The factors include: treatment condition (treatment and control), as a between-groups factor; time periods (four 10-minute periods), as a repeated-measures factor; and test session (pretest and

posttest), as a repeated-measures factor. The independent variables included: meditation training (with and without), and time periods within the vigilance task (four 10-minute periods). The dependent variables included: signal detection rate, false alarm rate, perceptual sensitivity (A'), and response criterion (B").

A 4 X 12 repeated-measures design was used to determine the effects of meditation training on thought intrusions. The four consecutive 30-minute meditation training sessions represented the single four-level factor. Only the 12 treatment group subjects that received meditation training were used in this portion of the study. Meditation training sessions represented the independent variable and reported thought intrusions the dependent variable.

Procedure

Subjects in both treatment and control groups performed the same vigilance task twice, as pretest and posttest.

Vigilance Task

Within the audiometric chamber, subjects were seated in a comfortable arm chair that was set facing a computer monitor. Subjects were instructed (see Appendix B) to remain seated during the task with their heads against the headrest so that the distance between the screen and their eyes remained fixed. The fingers of one hand were to

remain on or near the spacebar of the keyboard so responses could be made in a timely manner.

Two five-minute practice sessions were provided to familiarize the subjects with the task before the main session. Immediately preceding the first practice session, subjects received verbal instructions in conjunction with on-screen displays. The first screen displayed a static sample of two parallel lines of equal length, representative of a neutral event. By pressing the space bar the subject was presented next with a static sample of a critical signal in which one of the two lines were longer. It was pointed out that the longer line would always appear at the top of the two lines but could be on either side. Subjects were told not to expect any pattern in the critical signals since they were generated in a random fashion. By pressing the space bar again, the subjects were given 15 seconds to observe critical signals alternating with neutral events at one-second intervals so that repeated comparisons could be made. When the subjects indicated that they understood what was expected of them, the first five-minute practice was started. During the first practice session the experimenter stayed in the room and provided feedback to the subject. At the end of the five minutes the results showing hits and false alarms were displayed on screen and reviewed with the subject. During the review of the results, subjects were encouraged to keep

false alarms to a minimum. This was followed by the second five-minute practice session in which the subject was left to do the task alone. Again the results were reviewed and the subject was given a five-minute break before the main session started.

The main session was administered automatically by the computer and lasted 40 minutes. The computer presented the task in four continuous 10-minute segments that were each scored separately in terms of detection rate, false alarms, sensitivity, and criterion. Each 10-minute cycle contained 300 events, 10 of which were critical signals, and the remaining 290 were neutral events. Subjects were not allowed to review the results of their main sessions until they were debriefed at the end of the experiment. If the session just completed was the pretest, subjects were then scheduled for the posttest approximately six days in the future. The control group subjects were told to continue their normal daily activities until they returned for the posttest. Treatment group subjects received four 30-minute meditation training sessions over a five-day period. The routine used for the posttest was identical to the pretest and included the two five-minute practice sessions. While the practice sessions were not needed as practice in the posttest they served to equalize the amount of exposure prior to the main sessions.

Meditation Training

Meditation training was conducted within an audiometric chamber to provide a quiet environment that would facilitate the learning of meditation. Subjects were seated in the same arm chair as the one used in the vigilance task. They were instructed (see Appendix B) to sit with their backs straight and their heads up, away from the back of the chair. The headrest on the chair was removed to discourage subjects from resting against it. Subjects were instructed to hold the hand controller, that was connected to the computer, in a way that would allow the button to be pressed easily while their eyes were closed during meditation.

Instructions were given on a simple form of yoga meditation that required subjects to focus their full attention on the sensations and rhythm of breathing. Subjects were encouraged to take a minute prior to the start of the meditation to do a neck-stretching exercise that helped to release tensions in the neck and shoulder area. During the meditation, subjects were asked to count breath exhalations to themselves in cycles of 10 to maintain directed awareness towards their breathing. It was made clear that an active effort was to be made to maintain full attention on breathing and to report, with a press of the button, any intrusive thoughts that were unrelated to breathing. To

start the session, subjects pressed the button on the hand controller once, after the experimenter left the room.

The training sessions lasted for 30 minutes, at which time the computer would produce an auditory tone to alert the subject that the session was over. Subjects were not briefed on the number of thought intrusions reported until the end of the experiment. Each subject in the treatment group was given a 30-minute training session on four separate days. Sessions were grouped close together so that they spanned no more than five days. Pretests and posttests were never given on the same days as meditation training but either preceded or followed training by one or two days.

CHAPTER 3

Results

Dependent Measures

Signal detection rate, false-alarm rate, A', and B" were calculated for each 10-minute period during the vigilance task. Detection rate was derived by dividing the number of signals detected by the total number of signals presented. The false-alarm rate was calculated by dividing the number of false alarms recorded by the total number of nonsignal events within each 10-minute period. The nonparametric values of A' and B" were based on the computing formulas described in Appendix A. Overall performance scores for the four measures were obtained by taking the average across the four 10-minute periods for each individual.

Thought intrusions, which were self-reported during the meditation training sessions, were summed for each 30-minute session. Individual sum totals per session as well as average thought intrusions across all four training sessions were used in the analysis.

A three-factor mixed-design analysis of variance was used to analyze signal detection rates, false-alarm rates, sensitivity (A') values, and criterion (B") values. The

factors included: treatment condition, as a two-level between-groups factor (treatment and control); time periods within the vigilance task, as a four-level repeated-measures factor (four 10-minute periods); and test sessions, as a two-level repeated-measures factor (pretest and posttest). Means and standard deviations for detection rate, false-alarm rate, A', and B" are contained in Tables 1 and 2 in Appendix C.

Detection Rate Analysis

Mean detection rates over time periods are plotted for each test session in Figure 1. The line graphs clearly show a detection-rate decrement over time for all test sessions. The decrement was confirmed by a significant main effect for time periods (see Table 3). Multiple comparisons were performed using Tukey's Studentized Range ($\underline{Q}$) Test which found significant differences between periods: one versus three, $\underline{Q}(4, 66) = 6.32$, $\underline{p} < .01$; one versus four, $\underline{Q}(4, 66) = 5.53$, $\underline{p} < .01$; and two versus three, $\underline{Q}(4, 66) = 3.95$, $\underline{p} < .05$.

No other main effects or interactions were found to be significant. The Treatment X Period X Test interaction value was used to determine if there was an interaction between test sessions caused by differences in detection-rate decrement. It was determined that no differences in detection rate decrement existed. Figure 1 shows that

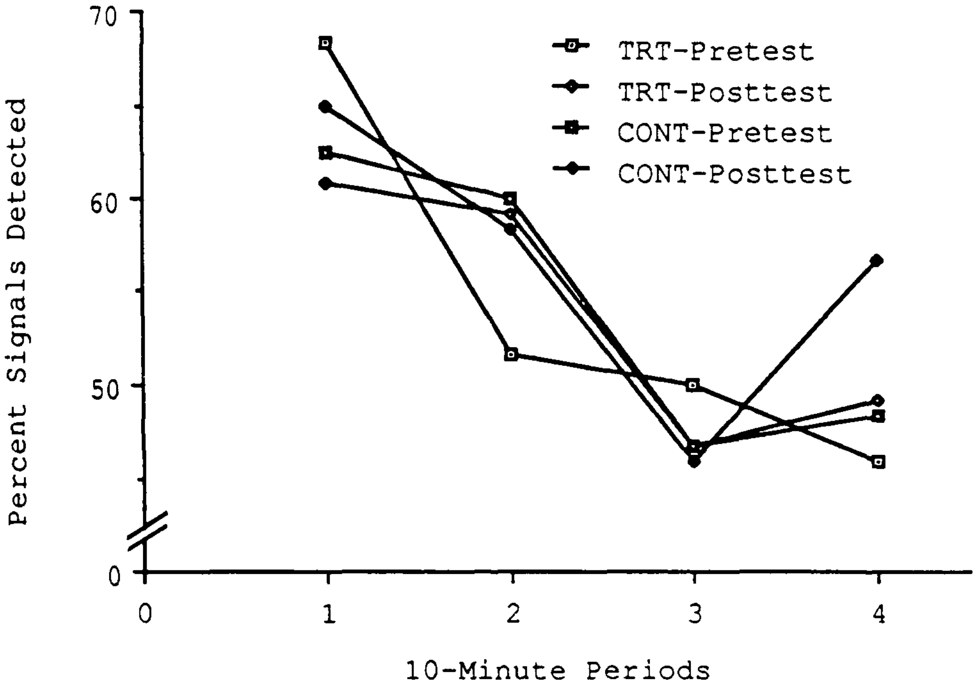

Figure 1. Mean percentage of signals detected as a function of time on watch (10-minute periods).

Table 3

Summary of Analysis of Variance for Detection Rate

Source	SS	df	MS	F
Treatment (A)	.0102	1	.0102	.08
Subjects in A (S/A)	2.9704	22	.1350	
Period (B)	.8318	3	2773	9.00*
A X B	.0427	3	.0142	.46
B X S/A	2.0329	66	.0308	
Test (C)	.0052	1	.0052	.18
A X C	.0052	1	.0052	.18
C X S/A	.6471	22	.0294	
B X C	.0585	3	.0195	.98
A X B X C	.0594	3	.0198	.99
B X C X S/A	1.3145	66	.0199	

*$p < .01$

approximately the same detection rate decrement was observed across all test sessions.

The Treatment X Test interaction value was used to determine if any differences existed between test sessions in overall detection-rate performance. There was no Treatment X Test interaction detected in the analysis. Mean overall detection rates for the test sessions ranged from 54% to 57% which indicated only minor differences between sessions.

Sensitivity (A') Analysis

In Figure 2, mean A' values are shown plotted across time periods for each test session. An apparent A' decrement for all test sessions can be seen in the line graphs. A significant main effect was found for time periods, confirming the presence of an A' decrement (see Table 4). When multiple comparisons were performed using Tukey's Studentized Range (Q) Test, differences were found between the following time periods: one versus three, $Q(4, 66) = 7.06$, $p < .01$; one versus four, $Q(4, 66) = 5.88$, $p < .01$; and two versus three, $Q(4, 66) = 4.70$, $p < .01$.

No other main effects or interactions were found to be significant. The A' decrement did not differ between test sessions, as indicated by the lack of a significant Treatment X Period X Test interaction. Figure 2 shows that a similar A' decrement occurred in each of the test

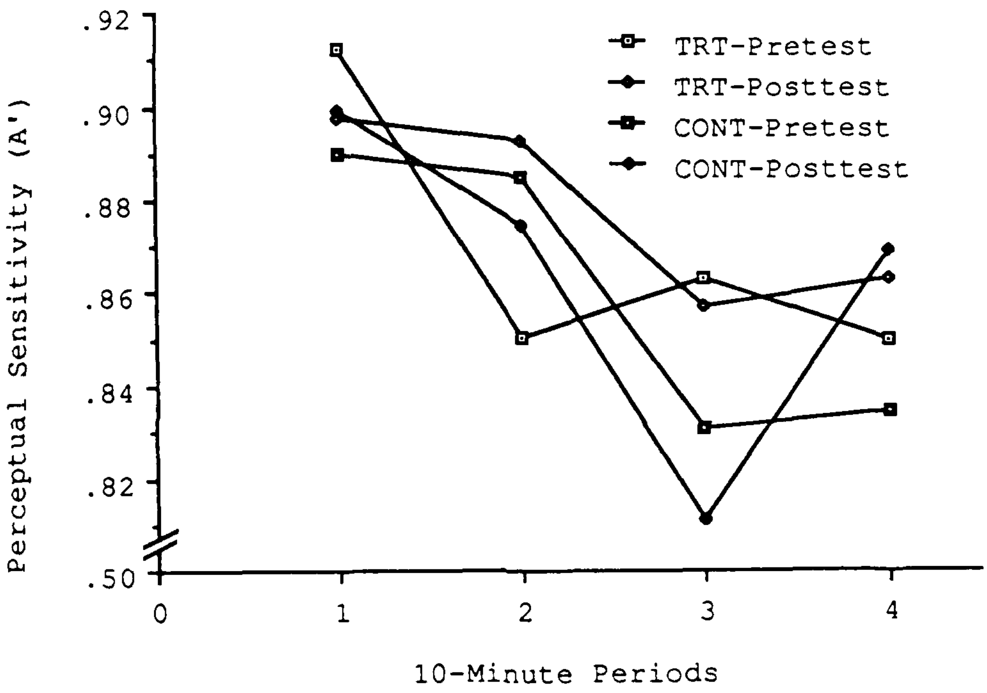

Figure 2. Mean perceptual sensitivity (A') as a function of time on watch (10-minute periods).

Table 4

Summary of Analysis of Variance for Sensitivity (A')

Source	SS	df	MS	F
Treatment (A)	.0062	1	.0062	.48
Subjects in A (S/A)	.2887	22	.0131	
Period (B)	.0964	3	.0321	9.05*
A X B	.0144	3	.0048	1.35
B X S/A	.2342	66	.0035	
Test (C)	.0018	1	.0018	.45
A X C	.0003	1	.0003	.08
C X S/A	.0886	22	.0294	
B X C	.0101	3	.0034	1.12
A X B X C	.0117	3	.0039	1.30
B X C X S/A	.1991	66	.0030	

*$p < .01$

sessions with only a small amount of interaction between test sessions and time periods.

The absence of a significant Treatment X Test interaction indicates overall sensitivity (A') did not differ between test sessions. Mean overall sensitivity (A') values ranged from .86 to .88, which represents relatively small differences between sessions.

Criterion (B") Analysis

Figure 3 shows mean B" values plotted across time periods for each test session. No consistent pattern can be seen in the line graphs for mean sensitivity over time periods. No significant main effects or interactions were identified by the ANOVA. The main effect for time periods seen in the detection rate and sensitivity (A') data, was not found in the criterion (B") data. See Table 5 for the ANOVA summary.

False Alarm Rate Analysis

A plot of mean false-alarm rates across time periods for each test session is presented in Figure 4. It is clear from the line graphs that the control group produced a higher level of false alarms than the treatment group on both pretest and posttest. A significant main effect was found for the between-groups factor that represented the treatment and control group (see Table 6). All other main effects and interactions were not significant.

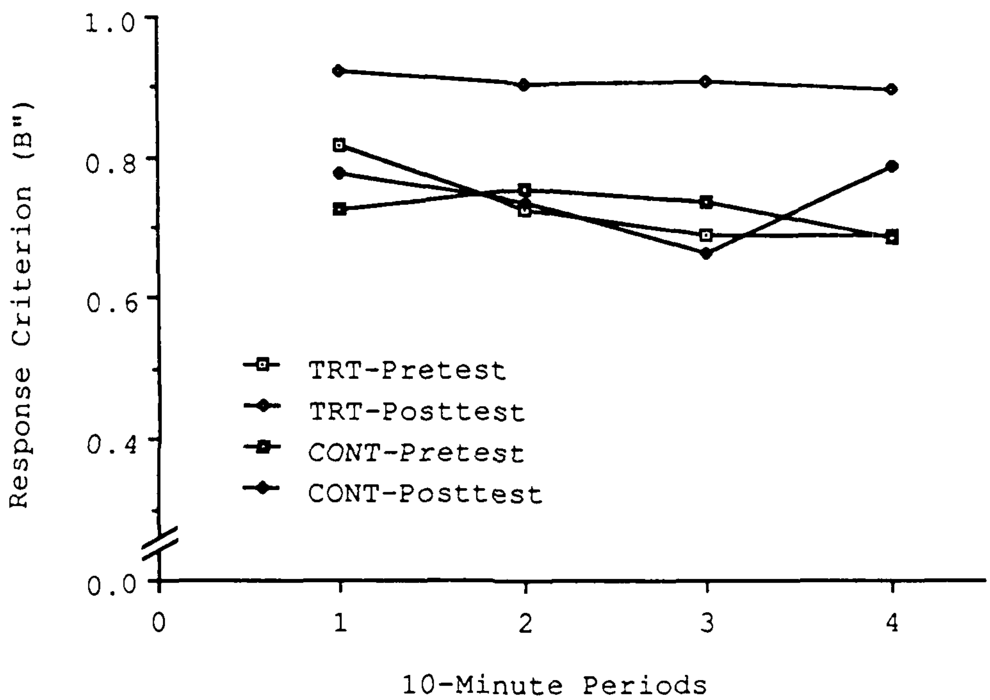

Figure 3. Mean response criterion (B") as a function of time on watch (10-minute periods).

Table 5

Summary of Analysis of Variance for Criterion (B")

Source	SS	df	MS	F
Treatment (A)	.3491	1	.3491	1.89
Subjects in A (S/A)	4.0588	22	.1845	
Period (B)	.0962	3	.0321	.46
A X B	.0304	3	.0101	.15
B X S/A	4.5919	66	.0696	
Test (C)	.4537	1	.4537	3.34
A X C	.3160	1	.3160	2.33
C X S/A	2.9888	22	.1359	
B X C	.0558	3	.0186	.28
A X B X C	.0918	3	.0306	.47
B X C X S/A	4.3076	66	.0653	

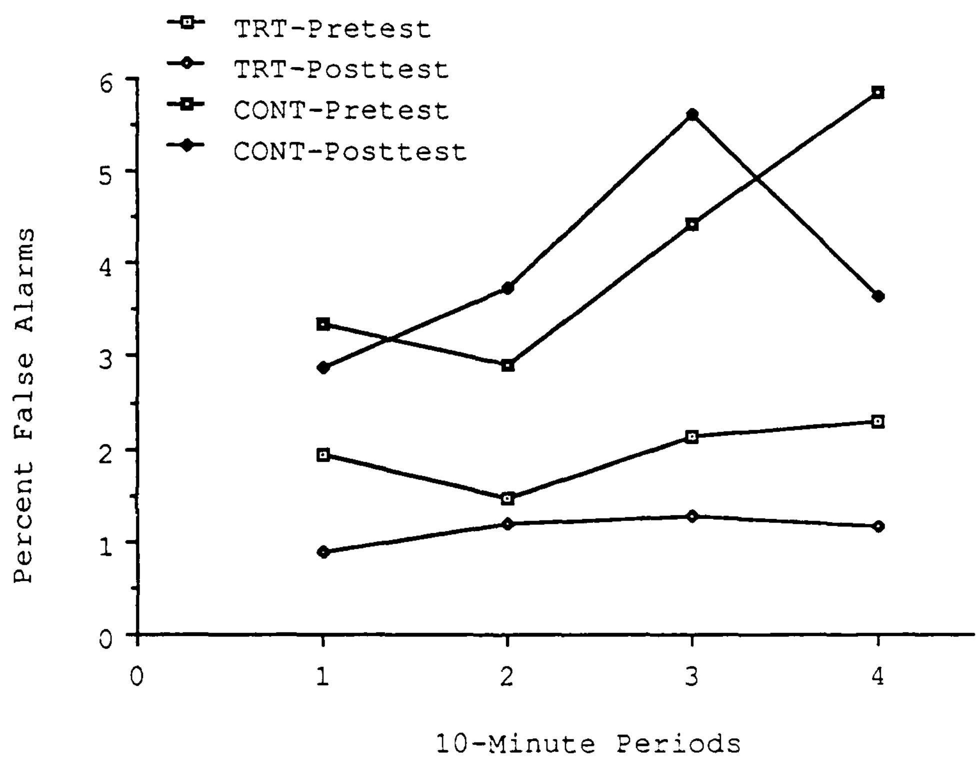

Figure 4. Mean false-alarm rate as a function of time on watch (10-minute periods).

Table 6

Summary of Analysis of Variance for False Alarm Rate

Source	SS	df	MS	F
Treatment (A)	.0303	1	.0303	6.73*
Subjects in A (S/A)	.0993	22	.0045	
Period (B)	.0049	3	.0016	1.28
A x B	.0022	3	.0007	.58
B X S/A	.0840	66	.0013	
Test (C)	.0012	1	.0012	.57
A X C	.0005	1	.0005	.25
C X S/A	.0462	22	.0021	
B X C	.0030	3	.0010	1.11
A X B X C	.0016	3	.0005	.56
B X C X S/A	.0603	66	.0009	

*$p < .05$

Thought Intrusion Analysis

Data for one of the twelve subjects in the treatment group were eliminated from the thought intrusion analyses due to excessive reporting of thought intrusions (2.67 SD above the mean). It is believed the subject received adequate meditation training, but misunderstood the instructions on reporting thought intrusions.

A one-way repeated measures analysis of variance and trend analysis were used to analyze the effects of meditation training on reported thought intrusions. The four consecutive meditation training sessions represented the four levels of the single repeated-measures factor. Total thought intrusions that were reported during each meditation session served as the dependent variable.

The mean number of thought intrusions for meditation training sessions one through four were 21.7, 16.3, 18.2, and 13.3, respectively, with corresponding standard deviations of 16.6, 9.6, 14.2, and 13.6. The means are shown plotted across training sessions in Figure 5. On the average, thought intrusions declined 38.9% between the first and last session. The ANOVA results show that training sessions produced a significant effect on thought intrusions (see Table 7). When Tukey's Studentized Range (Q) Test was used to make the multiple comparisons, meditation sessions one and four were found to be significantly different, $Q(4, 30) = 5.25$, $p < .01$. Orthogonal contrasts

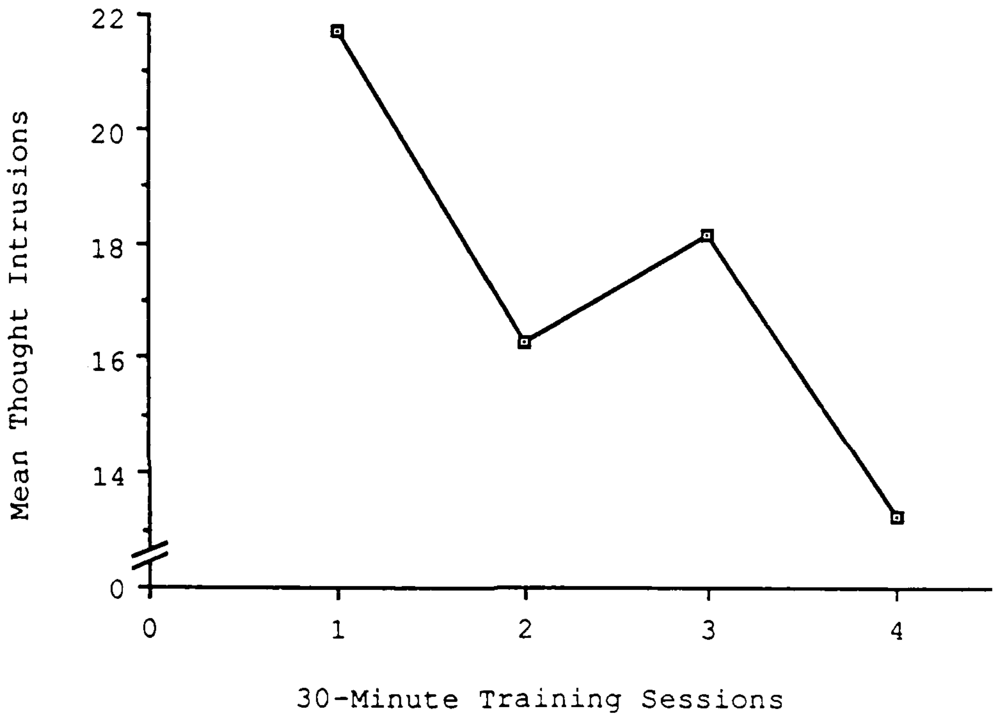

Figure 5. Mean thought intrusions across meditation training sessions.

Table 7

Summary of Analysis of Variance and Trend Analysis for Thought Intrusions

Source	*SS*	*df*	*MS*	*F*
Summary of Analysis of Variance				
Sessions (A)	414	3	138.00	4.47*
Subjects (B)	6602	10	660.20	
A X B	926	30	30.86	
Trend Analysis with Orthogonal Contrasts				
Trend				
Linear	302.56	1	302.56	9.80*
Quadratic	0.82	1	0.82	.87
Cubic	110.62	1	110.62	3.58

Note. Sessions X Subjects was used as the error term for the trend analysis.

*$p < .01$

were used to perform the trend analysis. A significant linear trend was identified, as shown in Table 7.

Correlation Analysis

Pearson *r* correlations were used to determine if thought intrusions, reported during meditation sessions, were related to either overall detection rate, overall sensitivity (A'), or overall criterion (B") values, recorded during the vigilance task. Ten separate correlations were calculated for each of the three relationships. Eight of the ten correlations were produced by correlating overall pretest scores and overall posttest scores with thought intrusions in each of the four meditation sessions. These eight primary correlations were used to determine if a relationship existed. Two additional correlations were obtained by correlating mean thought intrusions from all four meditation sessions, with overall pretest and posttest scores. Table 8 contains a listing of all correlations obtained.

Thought intrusions were found to be negatively correlated to overall detection rate. All eight primary correlations were negative, with two out of the eight being significant (see Table 8). A binomial test was used to determine the probability of eight out of eight correlations being negative, given the null hypothesis of $P = Q = .5$. Results of the binomial test show the probability to be, $p < .0039$. The two correlations based on mean

Table 8

Correlations Between Overall Performance Measures from the Vigilance Task and Thought Intrusions Reported During Meditation Training Sessions

	Meditation Sessions				
Measures[a]	1	2	3	4	Mean-TI[b]
Detection Rate					
Pretest	-.366	-.373	-.437	-.428	-.422
Posttest	-.375	-.521	-.615*	-.678*	-.568
Sensitivity (A')					
Pretest	-.425	-.354	-.367	-.343	-.395
Posttest	-.470	-.655*	-.572	-.686*	-.614*
Criterion (B")					
Pretest	.107	.313	.241	.317	.243
Posttest	-.278	-.425	.146	-.021	-.134

Note. Correlations shown are Pearson product-moment correlation coefficients, $df = 9$.

[a] Measures recorded from treatment group.

[b] Mean thought intrusions across all four sessions.

* $p < .05$

thought intrusions for all four training sessions were negative but not significant.

The primary correlations between overall detection rates and thought intrusions are shown plotted in Figure 6. It is apparent, from this figure, that the posttest correlations are stronger than the pretest correlations. To determine if meditation training had an effect on the strength of the relationship, a comparison was made between the correlations that represent the relationship at the start and end of training. The correlation between overall detection rate on pretest and thought intrusions in the first meditation session best reflects the relationship at the start of training. The correlation between overall detection rate on posttest and thought intrusions in the fourth meditation session best reflects the relationship at the end of training. With these two correlations the performance measures of detection rate and thought intrusions were obtained close together in time with no intervening events. At the start of training there was a nonsignificant negative correlation of $\underline{r}(9) = -.366$, $\underline{p} > .05$, and by the end of training there was a significant negative correlation of $\underline{r}(9) = -.678$, $\underline{p} < .05$. Thought intrusions accounted for 13% of the variance in overall detection rate at the start of training as compared to 46% of the variance at the end of training.

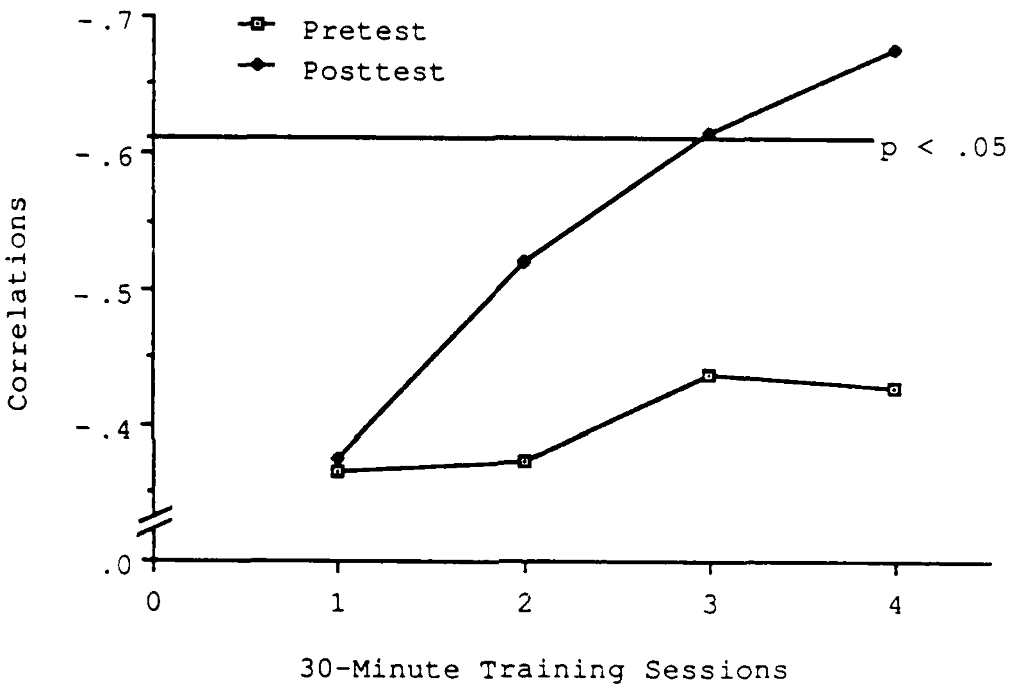

Figure 6. Correlations between overall signal detection rates and total thought intrusions for each meditation session.

To determine the reliability of the thought-intrusion measure, thought-intrusion scores for each meditation session were correlated with each of the other three sessions to produce a correlation matrix. All of the correlations were in the positive direction and significant at the .01 level; $\underline{r}(9) = .79, .84, .86, .87, .90$, and $.96$.

A negative correlation was also found between thought intrusions and overall perceptual sensitivity (A'). The eight primary correlations were all negative with two of the eight reaching significance, as shown in Table 8. The probability of all eight correlations being negative was calculated to be $\underline{p} < .0039$, as determined by a binomial test, assuming a null hypothesis of $\underline{P} = \underline{Q} = .5$. In addition, a significant negative correlation was found between overall A' on posttest and mean thought intrusions for all four meditation sessions (Table 8).

Figure 7 shows the primary correlations between thought intrusions and overall sensitivity (A') for each meditation session. To determine if meditation training had an effect on the inverse relationship that was found between thought intrusions and overall sensitivity (A'), a comparison was made between the two correlations that best represented the relationship that existed at the start and end of training. At the start of training (pretest with first session) there was only a small inverse relationship present, as indicated by a negative but nonsignificant

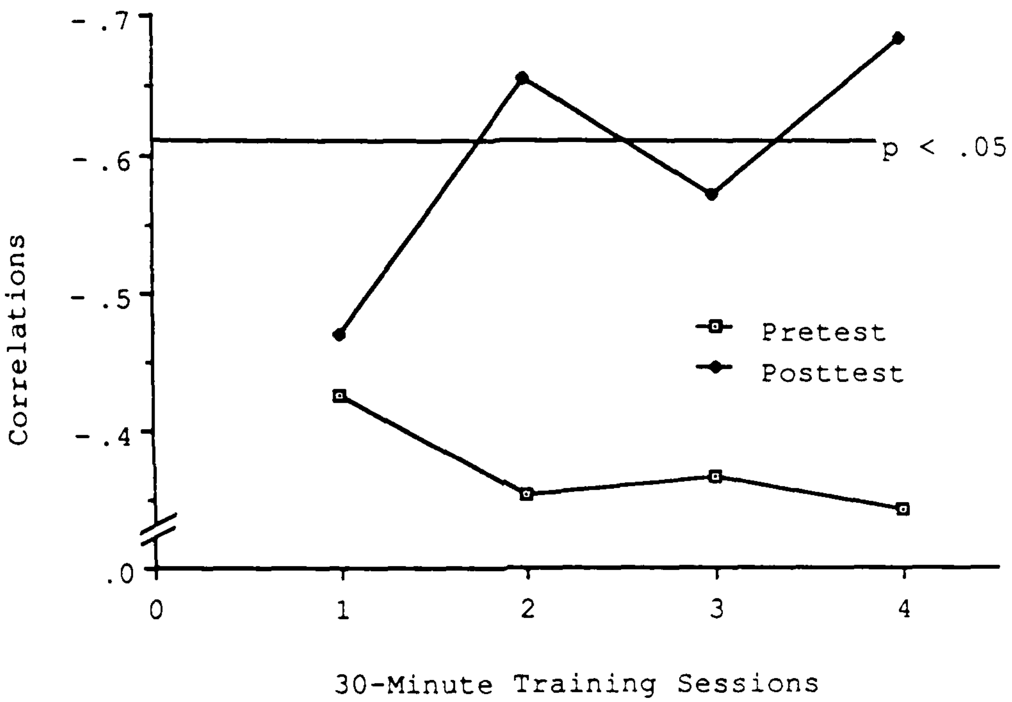

Figure 7. Correlations between overall perceptual sensitivity (A') and total thought intrusions for each meditation session.

correlation, $r(9) = -.425$. In comparison, at the end of training (posttest with fourth session) a significant inverse relationship was present, $r(9) = -.686$, $p < .05$. Thought intrusions accounted for 18% of the variance in overall sensitivity (A') at the start of training as compared to 47% by the end of training.

Thought intrusions were found not to be correlated with overall criterion (B"). All ten correlations relating to criterion (B") were nonsignificant, as shown in Table 8. Of the primary correlations, five were positive and three negative, a nonsignificant pattern.

CHAPTER 4

Discussion

This study investigated the relationships that exist between meditation training, thought intrusions, and vigilance performance. One of the main objectives was to test the Warm et al. (1977) findings to see if short-term meditation training produced the same effects on signal detection rates and vigilance decrement as long-term training. The results are mixed, providing support for the two hypotheses relating to thought intrusions, but failing to support the hypotheses dealing with signal detection performance and vigilance decrement. The findings related to each of the four hypotheses are discussed separately, beginning with the effects of meditation training on vigilance decrement.

Meditation Training and Vigilance Decrement

The first hypothesis predicted that meditation training would reduce the detection-rate decrement. This was not supported by the findings. The vigilance task produced a significant detection-rate decrement that averaged 7% by the second period, 16% by the third period, and 14% by the fourth period. However, the subjects who had received meditation training showed no change in

detection-rate decrement after training. The lack of a training effect on detection-rate decrement may be due to the limited amount of training that was provided in this study. Proficiency in meditation typically requires long-term training. It is likely that four half-hour training sessions do not provide a sufficient amount of time to develop the meditation skills needed to produce an effect on detection-rate decrement. In comparison, Warm et al. (1977) used meditators with an average of three years of experience. Additional research is needed in which more extensive meditation training is given using the same vigilance paradigm.

The detection-rate decrement that was found in this study appears to have been caused by a perceptual-sensitivity decrement and not by a shift to a more conservative criterion. Perceptual sensitivity (A') and detection rate showed nearly identical decrements over time while response criterion (B") remained essentially unchanged.

The findings of the present study are not consistent with the results of a survey conducted by Parasuraman (1979), of previous studies that used SDT measures. Studies, similar to the present one, that used a high event rate (greater than 24 per minute) and a simultaneous-discrimination task attributed their results to a criterion shift. The only studies that attributed their results to a sensitivity decrement were those that used a high event

rate together with a successive-discrimination task. In fact, all of the studies in the Parasuraman (1979) survey that used a simultaneous-discrimination task had found criterion shifts to account for their results. Parasuraman (1979) has asserted, based on the findings of his survey, that sensitivity decrements can only occur during successive-discrimination tasks employing high event rates. The present study, having found a sensitivity decrement with a simultaneous-discrimination task and high event rate, clearly contradicts his assertion.

One possible explanation for these contradictory findings is that the level of task difficulty used in the present study may have produced a high level of fatigue which could have contributed to the sensitivity decrement. In the present study, intense concentration on the visual stimulus was required to properly discriminate differences in length between two vertical lines, which may have resulted in a high level of visual fatigue. Sensory fatigue could have produced blurring or made it difficult to focus properly which would cause a sensitivity decrement. It was noted that subjects in the present study, frequently commented on the fatiguing nature of the task, often pointing out in particular the rapid rate of stimulus presentation that required constant sustained attention.

Simultaneous-discrimination tasks are generally considered to be less demanding and therefore less fatiguing, than successive-discrimination tasks which place a greater load on memory. It may be that the level of fatigue a task produces is a more accurate predictor of sensitivity decrement than the classification of simultaneous or successive discrimination. Once a certain level of fatigue occurs the resulting drop in sensitivity may be overpowering any criterion effects that dominate in the absence of fatigue.

In the present study short-term meditation training was found to have no effect on the sensitivity decrement (A'). Both the detection-rate decrement and sensitivity decrement are in close agreement, as would be expected if sensitivity changes were responsible for changes in signal detection. Whether or not more extensive meditation training can produce an effect on sensitivity decrement has to be determined by future research. Unfortunately, in the Warm et al. (1977) study, no SDT measures were used, so a comparison of A' values between experienced meditators and nonmeditators was not possible.

Meditation Training and Overall Performance

There was no support for the second hypothesis which predicted higher overall signal detection performance following meditation training. Here again, the results failed to match the Warm et al. (1977) findings, in which

experienced meditators had higher overall detection-rate performance than nonmeditators. As stated previously, short-term training in meditation may not be sufficient to produce the effects found in the earlier study. Meditation training also had no effect on overall sensitivity (A') or overall criterion (B").

Thought Intrusions and Performance

As predicted in the third hypothesis, an inverse relationship was found between overall detection-rate performance and thought intrusions reported during meditation training. Based on the results of the binomial test, it was determined that the negative correlations obtained represented an inverse relationship. The most plausible interpretation of this finding, based on previous research, would be that subjects experienced roughly the same level of thought intrusions during the vigilance task as they did during meditation, and that detection-rate performance was degraded as a function of thought-intrusion frequency. Since the inverse relationship was found for both pretest and posttest, this would indicate that the inverse relationship was general in nature, and not dependent upon training. This is consistent with the findings in the Antrobus et al. (1967) study, in which no training was given to subjects prior to the vigilance task. They had subjects report thought intrusions during the vigilance task and found that those with the highest number of

thought intrusions had lower detection-rate performance compared to those with the lowest number of thought intrusions. In the present study, thought intrusions were recorded only during meditation training.

Assuming that the number of thought intrusions remained stable across the meditation sessions and the vigilance task, the inverse relationship found between thought intrusions and overall detection rate would support the idea that thought intrusions degrade detection-rate performance. The inverse relationship also implies that a training program which improves a person's skill in controlling thought intrusions may lead to improved vigilance performance.

The pattern found in the correlations between overall detection rates and thought intrusions (Figure 6), suggests further that meditation training may have strengthened the inverse relationship that exist between the two variables. At the start of training there existed only a small inverse relationship as indicated by the nonsignificant negative correlation between overall detection rate on pretest and thought intrusions in the first meditation session. By the end of training, the inverse relationship was stronger, as indicated by a significant negative correlation between overall detection rate on posttest and thought intrusions on the fourth meditation session.

The remaining correlations provide additional support for the finding that meditation training strengthens the inverse relationship. Overall detection rate on posttest showed an increasing negative correlation to thought intrusions with each successive meditation training session. By the third and fourth meditation sessions the correlations had reached a significant level. In contrast, overall detection rate on pretest was not significantly correlated to thought intrusions in any of the four sessions.

The increasing negative correlations found between overall detection rate on posttest and thought intrusions on successive meditation training sessions, may be due to a combination of factors. One factor may be the cumulative effect that meditation training has on reported thought intrusions. A reduction in mean thought intrusions over training sessions was found in the present study, which indicates that meditation training had a cumulative effect. The possibility that meditation training produces a long-term effect on attentional ability that is capable of transferring to other tasks, may represent a second factor. One of the main objectives of meditation training is to develop a greater skill in controlling thought intrusions. As the skill develops, there is a high probability that it would transfer to other similar situations and possibly affect performance. The vigilance task used in this study was similar to the meditation training in that they both

required sustained attention on a repetitive stimulus. If the skills learned in meditation training did transfer to the vigilance task, any effects on performance would be seen only in the posttest. The posttest correlations were the only ones that reflected the increasing inverse relationship across training sessions. Therefore, the correlations found may be the result of both a transfer of training effect and the cumulative effect that meditation training had on reported thought intrusions over sessions.

Overall sensitivity (A') values on pre- and posttest were also found to be negatively correlated with thought intrusions from each successive meditation training session. This would suggest that a general inverse relationship exists between overall A' and thought intrusions, regardless of meditation training. This raises the possibility that thought intrusions may be interfering with perception in some way that reduces sensitivity.

A plot of the correlations, produced a pattern similar to that obtained with detection rate (Figure 7). However, the posttest correlations did not increase in as linear a fashion as did the correlations with detection rate. As with detection rate, at the start of training the correlation between overall A' and thought intrusions was negative but nonsignificant. By the end of training, there existed a significant negative correlation. This would suggest that meditation training strengthened the inverse

relationship between A' and thought intrusions, which is similar to the effect it had on the relationship between detection rate and thought intrusions.

Meditation Training and Thought Intrusions

This study confirmed that spontaneous thought intrusions can be reduced with meditation training, as predicted in the fourth hypothesis. Claims to this effect made by experienced meditators (Van Nuys, 1971), are supported by the findings of this study. The fact that a significant drop in thought intrusions occurred within four half-hour training sessions attests to the effectiveness of the meditation technique in reducing thought intrusions. Mean thought intrusions showed a significant linear trend as they declined by 39% over the four sessions. With additional training even greater reductions may be possible. The fact that thought intrusions declined in a linear fashion with meditation training, suggests that thought intrusions can be used as a measure of meditation progress.

The findings in this study are consistent with the Craver (1984) study. Craver determined that the technique for self-reporting thought intrusions, proposed by Van Nuys (1971), provided a reliable measure of thought intrusions. His conclusions were based on the results of a correlation analysis in which thought intrusions between meditation sessions were found to be highly correlated. The same

pattern of high correlations were found in the present study. This means that as subjects reduced their thought intrusions across meditation sessions they maintained their relative standing in the group. This is further evidence that thought intrusions remain relatively stable over time even while being reduced with training.

The total number of thought intrusions reported during each meditation session, in the present study, could be interpreted as an indicator of a person's skill level in controlling thought intrusions. In the present study it was assumed, that as a person's skill level changes, as a result of training, this would be reflected in the number of thought intrusions reported. It was also assumed that thought intrusions would remain stable over time, consistent with a person's skill level. These assumptions were supported by the present study which found that meditation training reduced thought intrusions, and that thought intrusions were highly correlated between sessions.

False Alarms

False alarm rates were recorded during the vigilance task so that the SDT measures of sensitivity (A') and criterion could be calculated. The overall percentage of false alarms generated during the vigilance task was relatively low, yet higher than originally anticipated when the experiment was designed. The false-alarm rates were at a

high enough level to make the SDT values of A' and B" meaningful and informative.

An analysis of variance was performed on false-alarm rates to determine if any main effects or interactions were present. It was determined that the control group generated significantly more false alarms than the treatment group. What caused this unexpected difference in false-alarm rates between the two groups is not clear. All subjects were randomly assigned to their respective groups and were given identical instructions prior to each vigilance task. The difference between the two groups can not be attributed to a meditation training effect since the treatment group had lower false-alarm rates on both pretest and posttest than the control group. The most likely explanation is that the random assignment of subjects to a treatment and control group failed to equalize the two groups in terms of their false-alarm rate performance. Given the relatively small sample size used in this study, the chance of forming unequal groups through random assignment is fairly high. The use of larger sample sizes in future research would help to eliminate this problem.

Since meditation training failed to produce an effect on any of the dependent measures used in the vigilance task, the interpretation of between-group comparisons did not become a critical issue. The hypotheses dealing with thought intrusions were analyzed entirely from treatment

group data and therefore were not affected by characteristics of the control group.

Conclusions

This study helped to further clarify the relationships between meditation training, vigilance performance, and thought intrusions. The findings are mixed and have raised new questions that will need to be addressed. Most importantly, short-term meditation training was found to have no effect on detection-rate performance or the vigilance decrement. There was, however, insufficient evidence to reject the Warm et al. (1977) findings which were based on long-term meditation training. It was determined that for this particular vigilance paradigm, the vigilance decrement was clearly caused by a sensitivity decrement.

The present study has shown that meditation training reduces thought intrusions as a function of time spent in training. This suggests that meditation training improves a person's ability to control thought intrusions. Randomly assigned subjects with no prior meditation training responded well to the training which indicates that meditation can be taught to the average person who may not have an interest in meditation.

Thought intrusions reported during meditation training were found to be inversely related to detection-rate performance. The implication of this finding is that thought intrusions degrade detection-rate performance on a

vigilance task. This findings is also consistent with the idea that control of thought intrusions is an ability that is fairly stable over time, and one that may transfer between similar tasks. However, there is the possibility that other unidentified variables are contributing to the inverse relationship between thought intrusions and detection rate.

The strength of the inverse relationship between thought intrusions and detection-rate performance, was found to increase with meditation training. This was attributed to the cumulative effect of the meditation training on reported thought intrusions and the possibility that the training effect transferred to the vigilance task, where detection-rate performance was affected.

By pulling together the various findings, it becomes clear that with sufficient meditation training there is reasonable cause to expect detection-rate performance to improve. If thought intrusions do in fact degrade signal detection performance, as suggested by the inverse relationship between the two variables, and meditation training does in fact produce long-term reductions in thought intrusions, then persons who successfully complete meditation training would be expected to show higher detection-rate performance on a vigilance task. This was not found to be the case in the present study when subjects were given two hours of controlled meditation training. Additional

research is needed to determine if more extensive, or more effective, meditation training under controlled conditions can produce the predicted effects. An alternative approach would be to train subjects to a specified criterion level of thought intrusions. If a meditation effect is eventually found, there is also the need to compare different meditation training techniques. This study used a form of yoga meditation in which the eyes remained closed and attention was placed on breathing. The Warm et al. (1977) study used TM meditators that practiced a chanting technique. While the two methods share common goals, they may produce slightly different effects on attention.

The false-alarm rate during the vigilance task was higher than expected, and reinforced the need for SDT measures to be used in conjunction with the traditional detection-rate measure. An analysis of false alarms uncovered an unexpected difference between the treatment and control group that suggests the need for larger sample sizes.

The lack of standardization in the vigilance research field makes comparisons between studies more difficult. The generalizability of these findings to other studies should be limited to vigilance paradigms which have similar task characteristics. In particular, it should be noted that a high event rate was used in conjunction with a fairly difficult visual discrimination task. The combination

of these two characteristics tend to produce a higher level of fatigue than is commonly found in most vigilance tasks. In addition, most of the early studies in vigilance used a much lower signal rate which could produce a different effect on detection-rate performance. In the present study, an effort was made to use a vigilance paradigm similar to the one used by Warm et al. (1977) so that any findings could be compared directly.

APPENDICES

APPENDIX A

Computing Formulas For A' and B"

Computing Formulas for A' and B"

Pollack and Norman (1964) have proposed a nonparametric measure of sensitivity (A') that can be calculated from a single pair of operating probabilities. The operating probabilities, when plotted, represent a point on the unit square. By drawing straight line segments from apex (0,0) and (1,1) through the point, a set of upper and lower bounds are formed. All possible receiver operating characteristic (ROC) curves are contained within the boundaries of the lines drawn. Sensitivity (A') is calculated by finding the minimum and maximum areas defined by the lines and taking their average. This approach is based on the finding that the area under the ROC can be interpreted as a percentage of signals detected in unbiased forced-choice tasks, regardless of the underlying distributions (Green, 1964).

Hodos (1970) has proposed a nonparametric measure of bias (B") based on the geometry of the unit square. The calculation requires a single pair of operating probabilities which are used to plot a point on the unit square. Hodos states that bias is related to the relative position of the point to the X axis, Y axis, and negative diagonal. To calculate bias (B"), straight line segments are drawn from the apex (0,0) and (1,1) through the point on the unit

square. Two overlapping right triangles are formed which share a right angle at the upper left corner of the square. The percentage difference in area of the two right triangles is interpreted as a nonparametric measure of bias.

Grier (1971) has provided computing formulas for the nonparametric measures of A' and B" based on the relationships defined by Pollack and Norman (1964) and by Hodos (1970).

$$A' = \frac{1}{2} + \frac{(PHIT - PFA)\,(1 + PHIT - PFA)}{4(PHIT)\,(1 - PFA)}$$

$$B'' = \frac{(PHIT)\,(1 - PHIT) - (PFA)\,(1 - PFA)}{(PHIT)\,(1 - PHIT) + (PFA)\,(1 - PFA)}$$

PHIT equals proportion hits and PFA equals proportion false alarms. The resulting nonparametric values have different ranges than their parametric counterparts, a fact which needs to be taken into consideration when interpreting the results. While d' can take on values of 0 or greater, A' is limited to a range of .5 to 1, with .5 representing complete insensitivity and 1 representing high sensitivity. Beta can assume any value greater than zero, but B" is restricted to values that fall between -1 and +1. Negative values generally represent a liberal bias (high false-alarm rate), while positive values are considered conservative (low false-alarm rate).

APPENDIX B

Instructions

Subject Instructions

Vigilance Task Instructions

The task you are about to perform will take you about one hour to complete. It will include two five-minute practice sessions, followed by the main session. If you wear glasses you should have them on at this time. During the task sit with your head against the headrest.

If you look at the screen you will see two vertical lines that are equal in length. This represents a normal signal to which no response is required.

Press the space bar to see a presentation of a critical signal. Critical signals contain two vertical lines of unequal length. Most of the time the lines will be the same length, but occasionally one of the two lines will be longer at the top. In this case the longer line is on the right. When a line is longer, it is always longer at the top and can be either the right line or the left line. Every time one line is longer you are to report this fact by pressing the space bar on the keyboard that is next to the arm rest of the chair. You must press the space bar quickly before the next set of lines appear. A new set of lines will be flashed on the screen for one-quarter of a second every two seconds.

Press the space bar to see normal signals alternating between critical signals at a slow speed. Try to distinguish between the two signals as they alternate back and forth.

The length of time between critical signals will vary randomly and may be minutes apart or only seconds.

Remain as still as possible while you work. Do not adjust the screen intensity level.

I will stay with you during the first practice session to answer any questions you may have.

At the end of the second practice session and the main session, the computer will display a message to let you know when you are finished. Press the intercom button at that time and I will open the door.

If a problem arises and you need to communicate with me, just press the call button on the intercom. Do not interupt the task if at all possible.

Meditation Instructions

I will expain and demonstrate, where I can, what you are to do during the meditation training sessions.

Sit back in the chair so your back is upright, to avoid slouching. Do not lean your head against the back of the chair. Let your body relax, but remain mentally alert.

It helps in meditation if you are relaxed in the neck area before starting. You can release tensions in the neck by doing a simple exercise. Let your head, neck and shoulders go limp, allow your head to roll forward with its own weight, then slowly roll your head completely around three times to the right and then three times to the left.

When you are seated comfortably and have completed your neck exercises you will be ready to begin the meditation. Pick up the hand controller off the table next to you and hold it in your right hand. The button on the controller should be in a position that is easy to press. If you look at the screen you will notice a messsage stating that the computer is waiting for you to press the button on the hand controller to start the meditation. After I have completed my instructions and have left the room, press the button once to let the computer know that the meditation has started.

After you press the button, you are to close your eyes and focus your complete attention upon the flow of air entering and leaving your body as you breathe. The focus of attention should not be of an intense nature but relaxed and may involve just the awareness of the ongoing rhythm produced by breathing. The depth and rate of your breathing should be automatic. Do not try to consciously control your breathing, just monitor your body's natural rhythm.

As you breathe, you are to count your exhalations to yourself from one to ten at which point you then repeat the count starting at one. So, every time you exhale (breathe out) you are to count silently. As soon as you get to 10, start over. This is to help you maintain attention on your breathing.

As soon as you are aware of a thought that diverts your attention away from your breathing, you are to do

two things: first, press the button once to report the thought intrusion, this allows the computer to keep track; second, place your attention back onto your breathing and resume the count of your breaths. Your intent should be to gain control over thought intrusions so that they occur less frequently and for shorter periods of time.

Deciding whether or not you experienced a thought intrusion can be difficult due to the subtle nature of some thoughts. The most obvious indication of a thought intrusion is when you lose track of your count. In those cases just report the thought intrusion and pick up the count at one.

Less obvious, are instances in which you attempt to divide attention by maintaining your count and entertaining stray thoughts at the same time. Such thoughts are to be treated as thought intrusions and reported.

If you find yourself counting past ten, this usually means that your attention is starting to drift and a greater effort to focus attention should be made.

As a rule of thumb, an intrusion is to be counted whenever you find that you have gotten caught up in a thought that requires a conscious decision to redirect attention back onto breathing. Very brief, fleeting thoughts that last no more than a second and and are caught instantly, should not be reported as thought intrusions.

Try to be consistent in the way you decide whether or not a thought qualifies as a thought intrusion.

It is important that you report thought intrusions as honestly as you can. Do not concern yourself with how many thought intrusions you have reported. Just report each one and continue on.

When you hear the computer buzz, this indicates that the session is over. You may be very relaxed at this time so take a minute to reorient yourself then press the call button on the intercom to let me know the session is over.

The meditation session will last about 30 minutes.

APPENDIX C

Descriptive Statistics

Table 1

Means and Standard Deviations for Detection Rate and Sensitivity (A')

Period	Treatment Group Pretest	Treatment Group Posttest	Control Group Pretest	Control Group Posttest	*M*
			Detection Rate		
1	.68(.13)	.61(.16)	.63(.19)	.65(.12)	.64(.15)
2	.52(.24)	.59(.14)	.60(.23)	.58(.18)	.57(.20)
3	.50(.25)	.47(.16)	.47(.15)	.46(.22)	.47(.19)
4	.46(.30)	.49(.23)	.48(.22)	.57(.18)	.50(.23)
M	.54(.25)	.54(.18)	.54(.20)	.56(.19)	
M	.54(.21)		.55(.19)		
			Sensitivity (A')		
1	.91(.03)	.90(.04)	.89(.05)	.90(.03)	.90(.04)
2	.85(.12)	.89(.03)	.89(.06)	.87(.05)	.88(.07)
3	.86(.06)	.86(.05)	.83(.07)	.81(.13)	.84(.08)
4	.85(.08)	.86(.07)	.83(.06)	.87(.06)	.85(.07)
M	.87(.08)	.88(.05)	.86(.07)	.86(.08)	
M	.87(.07)		.86(.07)		

Note. Standard deviations are in parentheses.

Table 2

Means and Standard Deviations for Criterion (B") and False Alarm Rate

	Treatment Group		Control Group		
Period	Pretest	Posttest	Pretest	Posttest	M
			Criterion (B")		
1	.82(.15)	.92(.06)	.73(.27)	.78(.15)	.81(.18)
2	.73(.48)	.90(.16)	.76(.26)	.74(.18)	.78(.30)
3	.69(.54)	.91(.14)	.74(.22)	.66(.40)	.75(.36)
4	.69(.55)	.90(.12)	.69(.27)	.79(.25)	.77(.34)
M	.73(.45)	.91(.12)	.73(.25)	.74(.26)	
M	.82(.34)		.73(.25)		
			False Alarm Rate		
1	.019(.013)	.009(.007)	.034(.031)	.029(.020)	.023(.022)
2	.015(.014)	.012(.021)	.029(.030)	.037(.035)	.023(.028)
3	.021(.026)	.013(.021)	.044(.058)	.056(.075)	.034(.051)
4	.023(.031)	.012(.020)	.059(.087)	.037(.056)	.032(.056)
M	.020(.022)	.011(.018)	.041(.056)	.040(.050)	
M	.015(.020)		.040(.053)		

Note. Standard deviations are in parentheses.

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